Authors comments to referee #1

This is an interesting ms that I would like to see published. The idea of moving boundaries depending on salt dissolution is, to the best of my knowledge, novel. Discontinuous finite element schemes have been used before, but probably never to flow/transport/dissolution problems in a fracture. I do, however, see some technical inaccuracies and several weaknesses in how the test cases are explained and how results are presented. Details are given below in the General Comments section. For these reasons, I recommend acceptance of the manuscript with moderate revisions.

Introduction. Other publications relevant to the topic should be included in the introduction. Examples of a model that simulates flow/transport/dissolution/ precipitation/variable-density/K-changes is in Graf and Therrien (2007b, Adv. Water Res.), and references therein.

Will be included in the revised version.

Simulation domain. It is unclear to me what exactly the simulation domain is. On P58L25, it is said that only the "fluid" phase is simulated. You cannot simulate a phase, only processes that happen in a phase. Also, you probably mean the "liquid" phase. A "fluid" phase does not exist. Simulating processes in the liquid phase seems to be in accordance of what you say on P66L3f.

Indeed, what is meant by fluid is the liquid phase; this will be corrected in the revised version.

However, looking at the domain definition (Fig. 1) and on results (e.g. Fig. 5) suggests that you are simulating processes in the Upper Aquifer as well. Is that so? This is very confusing to me because you are showing boundary conditions and fault zones that reach into the Upper Aquifer in Fig. 1, and you are presenting salt distribution in the Upper Aquifer in Fig. 5. The question therefore is, what exactly is your simulation domain, and does it include the Upper Aquifer (as Figs. 1 and 5 suggest) or are you only concentrating on the fracture in the Lower Aquifer (as you appear to state on P58L25 and P66L3f)? These questions also lead to the question of the transport boundary conditions in your model domain, which are never explained. "CH" in Fig. 1 should be replaced by "constant head".

The simulation is applied on the entire domain as shown in Fig. 1. The domain is considered as a porous media that has the characteristics as shown in Table 1. Darcy's equation is used to approximate the flow in the Upper Aquifer, in the fault zones and in the Lower Aquifer, except in the void below the Lower Aquifer and on top of the salt formation, where the Stokes equation is applied. A constant concentration is imposed at the top of the salt layer. This discussion will be added to the revised manuscript and a new table will be added. CH will be replaced with constant head.

Truncation error control. Referring to P60L5ff, a more recent local truncation error control scheme for variable-density flow in fractured-porous rock was published by Hirthe & Graf (2012, Adv. Water Res.), which the authors should reference.
Will be added in the revised version.

Mathematical terms of Eqs. (1) and (2) should be explained right after Eq. (2).

Also added in the the revised version.

Mass fraction. Are you sure, C is mass fraction? The density equation in Eq. (4) suggests that C is relative concentration that varies between 0 and 1, while mass fraction would vary between 0 and 0.35. What is the exact meaning of rho1 and mu1? Fluid properties at what concentration, at relative concentration of 1 or at mass fraction of 0.35? There is a technical inaccuracy here, which should be resolved. If your code is actually using exactly Eqs. (4), the inaccuracy may actually be major. Please clarify

C is the relative concentration and it varies from 0-1. It is dimensionless. ρ_1 and μ_1 are the density and viscosity of the high density liquid (saltwater), respectively, ρ_0 and μ_0 are the density and the viscosity of the liquid at zero concentration, respectively. This correction will be added to the revised manuscript.

Dissolution. You are simulating dissolution, but not precipitation. Dissolved salt may precipitate elsewhere downstream. It is necessary to comment on the effect of that simplification. Also, dissolution parameter lambda does not seem to be temperature dependent, which it really is. Again, the effect of that assumption must be discussed. For a reference of temperature-dependent dissolution and precipitation parameters, you may look at Graf and Therrien (2007b, Adv. Water Res.).

In our study, we do not account for the full dissolution kinetics of rock salt, which creates both dissolution and precipitation, and depends also on temperature variations. Temperature variations are not considered very significant on the comparably shallow simulated cross section with depths less than 200m. We do agree that there is the possibility of precipitation. However, no typical recently precipitated rock salt minerals have been observed in any drill core in the area, if any, only dissolution voids. Therefore we decided to only simulate dissolution.

Section 3. Definition of the conceptual model should be improved (as said above), and the same is true for the presentation of results. Why do you need a pumping well at the WNW side? Are you actually pumping? If yes, this is not possible because your model is 2D. If no, why the pump? You can simply assume constant head, without mentioning the pump. Also, what is the physical justification for your choice of flow and transport BCs (the latter are not defined)? The flow BCs suggest flow from ESE to WNW, is that so? The flow physics of all 3 test cases must be explained much more clearly. It looks as though much detail is spent on the numerical explanations, and that the physics of the test cases is not explained as clearly. This must be improved so that the reader understand what is happening physically in the 3 test cases. The same is true for the presented salt profiles. An interpretation of presented salt profiles is mostly missing. There is much more science in your results, which should be developed more fully

The structural and hydraulical boundary conditions are based on an existing 3D geological model of 47 faults and 4 faulted horizons of the main aquifers-aquitards, and a related 3D regional groundwater model (Spottke et al. 2005, Zechner et al. 2011). We are actually pumping in the Upper Aquifer due to large-scale industrial pumping at the field site. The pumping rate is 0.15 m3/s, which equals to an imposedhead of 251 m in the 2D model section. In two related studies (Zechner et al .2011, Zidane et al. 2014, Contaminant Hydrology, in press) the effect of the pumping rate and the well depth (into the aquifer) are studied in details. The effect of the pumping in a 2D domain for a well of length L (depth into the aquifer) is considered by dividing the pumping rate over the finite elements that intersect with the well within the Upper Aquifer. The individual pumping rate of each finite element is then assigned to the sink/source term (Qs) in the transport equation. The flow and transport boundary conditions are added to Fig. 1. For the transport boundary conditions a zero constant concentration (relative concentration) is imposed at the inlet ESE boundary and is set to one in the lowest layer of the lower aquifer (Fig. 1a). A new figure (attached) will be added to show the flow directions in detail. In all the simulated test cases the flow directions show a similar pattern, with a general flow direction in the Upper Aquifer going from the ESE boundary towards the pumping well at the WNW boundary The detailed figure further shows that some vectors are indicating flow underneath the well on the bottom of the aquifer, which then rises upwards parallel to the well, flows towards the WNW fault zone along the top of the Upper Aquifer, before it drops into the Lower Aquifer along the WNW side of the fault zone.. This discussion, and also a morde detailed description of the simulated concentration distribution in the 2D section will be added to the revised manuscript.

Section 4. The two §§from P74L6 to P74L21 belong into the Conclusions section.
Will be added in the revised version.
Fig. 12 should be presented much earlier to set the stage for your investigations.
Will be added in the revised version.

Authors comments to referee #2

What is the relative importance of the main factors / parameters / boundary conditions, contributing to regional dissolution process a) regional flow field, b) local flow field, vertical transmissivity of fault zones, permeability of overlying aquifer, transmissivity of bedding plane "fracture", hydraulic gradients of regional fault-fault / fault borehole configurations, etc. There might be others. I am of the opinion that a more systematic parameter study should be attempted.

The effects of different parameters on the dissolution process were extensively studied in recent publications. Zechner et al. 2011 described the role of dip of geologic formations in a setting of horst and graben structures on salt dissolution: they found an increase of dissolution rates with increasing dips. Zidane et al. (Contaminant Hydrology, in press) studied the influence of different aquifer geometry parameters affecting the salt dissolution. The authors (Zidane et al., in press) found that the structure of the normal faults has the highest impact on the dissolution process. In this paper, however, we present a model that relates the dissolution process to the subsidence rate by developing a moving boundary interface between the lower aquifer and the salt layer. This discussion is added to the revised manuscript.

Please address the long-term effect of the salt dissolution (steady state conditions). Is the initial rapid dissolution a boundary, initial condition effect (modeling artifact?)? The

more relevant results are those of the long-term dissolution process and should be stated as such. The comparison of the field observation with the simulated data should be on this basis.

At the time t=0 the aquifer is initially filled with freshwater, hence the concentration is set to zero in the entire domain including the lower aquifer. Hence, the high concentration gradient (∇C) at the early time steps induces the high dissolution rate at the beginning of the simulation. The field equivalent to this simplification would be a sudden freshwater access to the top of the rock salt formation, which would lead to a drastic increase of the concentration gradient. With the presented boundary conditions, the steady state conditions are reached after 3 years of simulation. This discussion is added to the revised manuscript.

Address aspects of (absence) dissolution kinetics.
See comments addressing Dissolution of 1st referee.

Provide detailed figure of local flow patterns / concentration distribution between well and fault zone. Such a diagram would highly contribute to the reader's understanding of what's going on. It could also include a diagram of the spatial distribution of mass flux.

Will be added in the revised version.
The structure of the manuscript is great, as well as the presented diagrams (please add a figure, described in 4.)). Attention should be paid to spelling and a few "unusual" terminology, such as:
a.p.12256, L6 - "reactive fractures" – unusual expression
b.L16 – "vertical mass loss" rather than "vertical dissolution"
c.L23 – "undersaturated" rather than "sub-saturated"??

a) reactive fractures will be replaced by "opening voids, or fractures" in the revised version.
b) The vertical dissolution term is used to point out that no dissolution is accounted for in the horizontal direction (See Fig. 2).
c) c) The term sub-saturated has been used in the same context (see Zechner et al. 2011).